# THE GULF STREAM PROJECT

BUREAU JACQUES PICCARD - LAUSANNE

# THE GULF STREAM PROJECT

BUREAU JACQUES PICCARD

LAUSANNE 1966

# A B S T R A C T

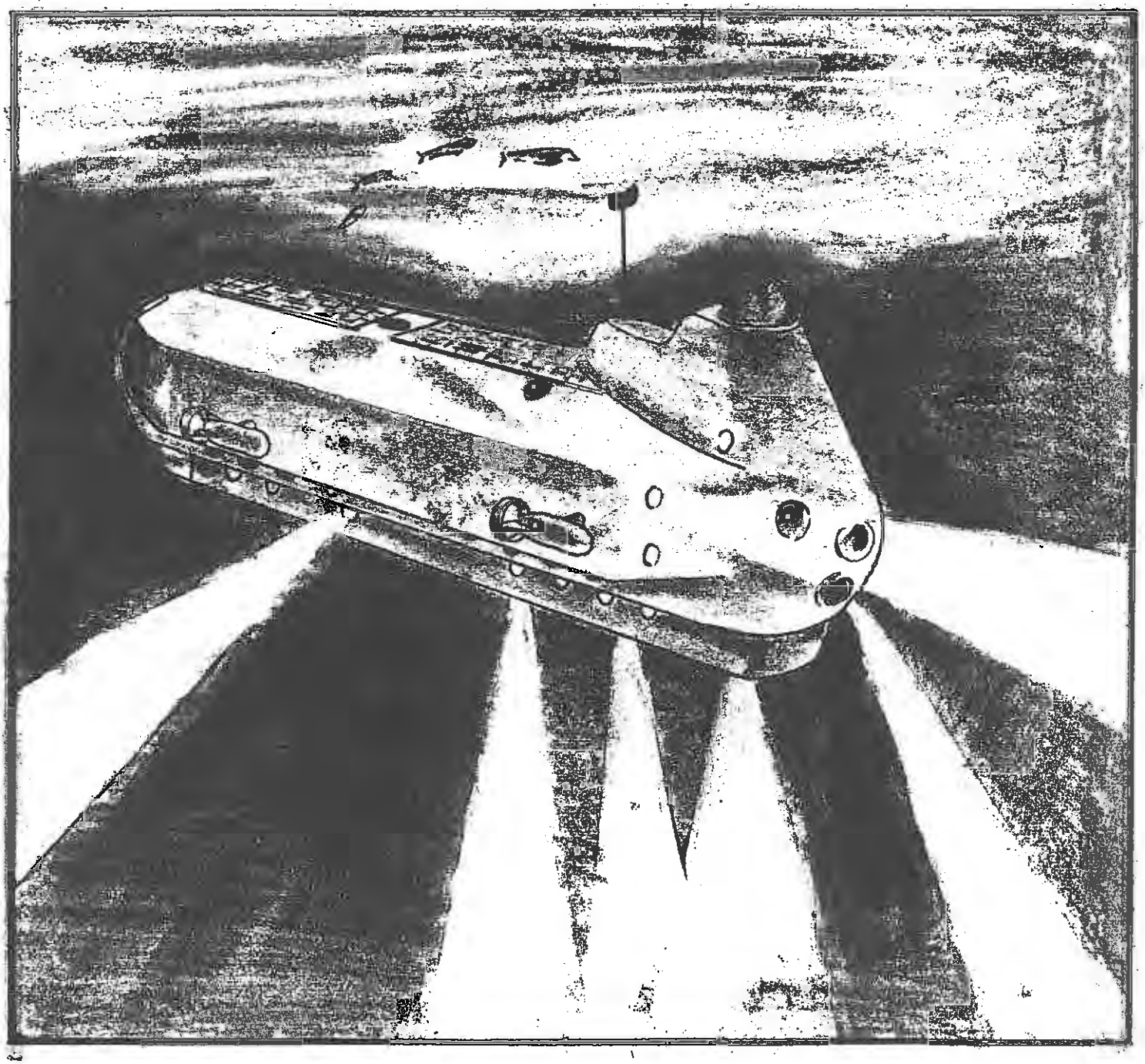

| | |
|---|---|
| Purpose | : Underwater exploration of the Gulf Stream between Florida and Nova Scotia.<br>Average depth: 600 feet (with excursions up to 300 feet and down to 1200 feet. |
| Oceanographic research | : Marine biology<br>acoustic<br>deep scattering layers<br>various |
| Time involved | : 15 months, including the construction of the mesoscaph<br>4 to 6 weeks spent in the depth of the Gulf Stream without surfacing |
| Money involved | : Between 700,000 and 800,000 $ (depending on the equipment and the program), including 403,500 $ for the construction of the new mesoscaph. |


THE GULF STREAM

off the American Shore

# PX - 15

# SUBMERSIBLE VEHICLE



# I. INTRODUCTION

The Gulf Stream is an important branch of the wide current system involving the whole North Atlantic Ocean. Technically, the name, "Gulf Stream", is reserved for that part of the current flowing at some distance off the shores of the United States between Cape Hatteras and Nova Scotia. However, for general purposes, the name applies to the current which, when leaving the Gulf of Mexico, turns north around Florida, runs along the Eastern coast of the United States until it reaches, roughly, the latitude of New York and then turns east into the middle of the Atlantic Ocean. From there, the current divides itself into two main branches. One of them returns to the south and joins the equatorial currents and the other one goes to the north, envelops Great Britain, enters the Norwegian Sea and returns west skirting Greenland.

With its flow reaching several millions of tons of water per second, the Gulf Stream gives to Northern Europe some ten thousand billion calories per second that have been carried from the warm Atlantic and the Antilles. Quite clearly, such an important complex has a basic influence upon the life of the Atlantic and its environs.

Famous navigators and scientists of the past centuries such as Cabot, Ponce de Leon, Benjamin Franklin, Arago, Maury and others emphasized the importance of the stream.

For example, Franklin already studied its temperature down to depths of three hundred feet.

The scientific, economic and even military importance of the Gulf Stream is recognized now by every specialist, and careful studies have been continued over the past several years. Several laboratories on the eastern coast of the United States are collecting data currently.

These studies are being made from surface vessels. However, it is evident that for many observations the surface provides a very poor operative base; no doubt that an underwater platform would offer much better and advanced possibilities. J. C. Swallow created an interesting possibility by launching into the Gulf Stream small buoys constructed for floating at pre-determined depths. By tracking these buoys, scientists could obtain better knowledge of the characteristics of the underwater currents. With the advent of the bathyscaph and mesoscaph, however, a new idea appeared :

TO SEND INTO THE DEPTHS OF THE GULF STREAM
A TEAM OF SCIENTISTS WHO WOULD STAY THERE
FOR SEVERAL WEEKS AND ACHIEVE A COMPLETE
SURVEY WHILE DIRECTLY BEING IN SITU.

The present project consists of letting a vehicle drift underwater into the Gulf Stream. Several dives

will be made with an ultimate goal of a four to six week underwater exploration between the Gulf of Mexico and Nova Scotia. During that period the vehicle will not surface.

o o

o

From the technical point of view, the main problem consists of having a deep-sea submarine capable of the following performances :

a) Ability to withstand high seas

b) Capacity for five to six people, and their support, for a one to two month underwater trip

c) Sufficient navigational instrumentation

d) Ability to move at any time to surface or to bottom or to another location in the stream

e) Vertical stability, that is, having neutral buoyancy in midwaters because of the hull being less compressible than water. The slightest tendency to move up or down will then be automatically annihilated by the difference of density of the surrounding water itself.

It appears that only a vehicle of the mesoscaph type, like the AUGUSTE PICCARD, recently built in Switzerland, completely fulfills all these conditions.

The mesoscaph (meaning ship for medium depth - as bathyscaph means ship for great depth) has been built un-

til now in one model as a scientific and/or touristic underwater vehicle. It can reach 2500 feet with a safety factor of 2. Since July 1964, it has made some 1100 dives into the Lake of Geneva, Switzerland, with more than 32,000 passengers. Average depth was about 300 feet, some dives reached 1000 feet.

## II. THE PX - 15

For the Gulf Stream Project a vehicle similar to the AUGUSTE PICCARD has been conceived. Its code-name is PX - 15.

### Main characteristics of the PX - 15

- weight : 100 tons
- length : 42 feet
- width : 13,4 feet without motors
  17 feet with motors
- height : 19,7 feet
- thickness of the steel plate : 1,4 "
- visibility : 20 portholes (placed all around the hull and
  5 portholes directed towards the surface
- outside lighting : 20 search lights (or more, if required) of 500/1000 W
- personnel capacity : 5 people for 6 weeks, 10 for one day or more, if required
- air supply : 6 weeks
- normal operating depth : 2000 feet
- battery : 750 kwh (in 1000 hours)
- propulsion : four 25 HP AC engines (AC current provided through static converters). The propeller can be used horizontally or vertically
- access : two 30 " hatches
- usefull payload : 5 tons or more, according to circumstances
- safety ballast : 5 tons

- speed : 5 to 6 knots
- draught : 11,7 feet
- one pair of manipulators (if desired).

The PX - 15 is equipped with items having already proved to be satisfactory in the industrial and oceanographic fields, as well as with some electronic instruments of latest achievement.

o o
o

The main part of the PX - 15 is evidently its hull. It is a cylindrical body made of steel plates 35 mm thick and closed by 2 hemispheres, and reinforced every 700 mm by a steel ring. Total length is 12,85 m; outside diameter 3,50 m. It is equipped with 25 plexyglas conical portholes (inside diameter 15 cm, outside 31 cm, thickness 8 cm). Collapsing depth of the hull is about 4000 feet.

The Krupp steel N-A-XTRA 55 (yield point 55 kg/mm2 or 78,000 psi) has been selected for the cylindrical hull and the Krupp steel WEL-MONIX (yield point 50 kg/mm2 or 71,000 psi) for the two hemispheres.

On both sides of the hull there are the water-ballasts giving a good stability and floatability when the

mesoscaph is on the surface. These ballasts are removable in order to facilitate transportation.

Below the hull, the keel, also removable, contributes to the stability and is housing the electric battery which is operating directly under pressure. The capacity of the battery is 2500 Ah under 300 V (750 kwh in 1000 hours). None of the gaz produced can penetrate inside the hull.

On the ballast tanks there are four AC electrical engines, each one of 25 HP and with one propeller. The axis of each motor support can be turned in such a way that the propeller can be used for diving or coming up, as well as for forward and backward propulsion. The AC current is produced by two static converters fed by the battery. Speed can be regulated (by changing frequency and voltage) from 0 to the maximum. Submerged speed is about 5 knots.

o o

o

The inside of the PX - 15 is equipped with both, laboratory and living facilities, including showers, kitchen, a.s.o. 5 people will be able to live in it with sufficient comfort for about 6 weeks.

At the bow, a large cockpit is installed for the pilot. At the stern, the "living-room" and the kitchen

for the crew. A central corridor runs between berths and working places from bow to stern.

The inside atmosphere is fully conditioned, mainly by KO2 candles; these absorb $CO_2$, some odors and some water vapor and provide for the oxygen; beside this, charcoal and maybe sillicagel will complete the system for purifying and drying the atmosphere.

Previous experiments with the bathyscaph showed that 0,25 litre of oxygen per man and per minute is sufficient for people remaining quite. 0,3 to 0,4 litre per man and per minute were used on board of the SEAWOLF (average for 135 men and 60 days) for one of its long cruises.

It can be noted here that $CO_2$ absorber is more immediately important than $O_2$ supply; $CO_2$ proportion in breathing air has not to be kept higher than 1 % for a long period of time.

o o

o

The physical main characteristic of the PX - 15 is its static stability. In opposite to conventional submarines, the mesoscaph is less compressible than water; this means that once equilibrated in weight and temperature, it can float in midwater with a tendency of stay-

ing at the same depth. The conventional submarine on the contrary has always a tendency to dive deeper or to come up and it cannot stop at a given depth by itself without pumping water in and out.

The stability of the mesoscaph allows it to float for weeks or months without spending energy and without making any kind of noise. This is the key of the Gulf Stream project. Compressibility of water is $50,0 \cdot 10^{-6}$ cm2/kg (at 10° C between 1 and 25 atm); compressibility of the PX - 15 is $35 \cdot 10^{-6}$ cm2/kg.

o o

o

The PX - 15 could be built in Switzerland by the Company which already built the PX - 8 AUGUSTE PICCARD (Giovanola SA, Monthey/Switzerland). By using the same tooling still available, an appreciable amount of money could be saved. The preliminary tests could be made in the Lake of Geneva, some 15 miles from Monthey which would give the advantage of staying close to the factory. Even when considering the cost of transportation from Switzerland to the United States, it is still cheaper to build the new mesoscaph in Switzerland.

## III. THE PORT ST. LUCIE CONFERENCE

On May 7, 1965, a first symposium was held at St. Lucie-Country Club, near Fort Pierce/Florida. After a long meeting and several discussions with oceanographers and engineers, the following points, among others, have been established :

1) The best time of the year for the drift is May and June

2) The most suitable depth to be explored during the first trip is about 200 meters (roughly 600 feet). There from some incursions can be made up to 100 m (300') and down to 400 m (1200'). There is a good chance to observe giant squidds at 100 m deep and nearly certitude to observe various big fishes such as sail-fish. While at 400 m especially sharks and tuna-fish may be observed.

3) At 200 m deep, the temperature in the middle of the Stream will be between 15 and 17° C. As the temperature of the Stream increases towards east, the drift can be controlled by the temperature changes. For instance off Fort Pierce, within 80 km the temperature at 200 m deep increases from 9 to 20° C.

4) The average speed of the Gulf Stream off the American shore is about 4 knots at the surface, 1,5 to 2 knots

at 200 m deep and 1 knot at 400 m deep. Maximum speed may be expected in May, minimum speed in October. The secondary drift towards east may be expected to be about 1 to 2 miles per day.

In order to stay in the middle of the Stream, we then will have to use our own power every day for about one hour, directed toward west.

5) Various other points concerning life supply and organization on board while submerged for several weeks have been discussed. More information could be obtained by discussing with the Army Quartermaster Corps, Natick/Mass., the Polaris people and the Naval Medical Center.

## IV. THE GULF STREAM DRIFT

The expedition can now be visualized like this :

After having made a few preliminary dives (1 to 3 days), the PX - 15 will be towed off Miami and the dive will start at the exact place established in advance.

The buoancy will be extremely carefully checked. A difference in weight of one pound would change the depth of about 10 feet, if the temperature is adjusted and constant. Theoretically, the mesoscaph could be overcarried at the surface with 60 pounds to be equilibrated at 600 feet. However, it will not stop at the correct depth for the first time, but will oscillate around it with a decreasing amplitude. Little by little, as the temperature will regulate itself, the amplitude of oscillation will be reduced. The hull will relatively soon take the temperature of the sea. The complete phenomenon is, however, rather complexe as several factors will interfere, such as :

- change of temperature of the water with depth
- change of temperature of the water with latitude
- change of temperature of the water with longitude

- heat production of the crew (between 7 and 800,000 calories per hour)
- heat production of breathing equipment (some 260,000 calories per hour)
- heat production of various equipments (some 50,000 calories per hour).

The total internal heat production will equal about 1300 W. This amount of heat will be appreciated and will allow the crew to make some stays at a depth of 400 m where outside temperature is only about 10° C.

We do not expect to find the perfect equilibrium or even a small amplitude system before one day or more; we even expect that the mesoscaph will from time to time jump out of its equilibrium system, for instance under the influence of some "internal waves" having easily an amplitude of 300 feet. By using our negative tanks, we will be able to neutralize part of the external influences, and this will contribute to avoid any monotony on board.

As said before, the crew will most probably consist of five people including the chief of the expedition. Everybody will have his turn of watch, probably four hours every time. The watchman will have to keep in touch with the surface (see below), he will check the power consummation, the breathing air system and the depth. Quite evidently, however, the authorized depth will never be overpassed, as a fully automatic device will drop the

safety ballast if for any reason the mesoscaph is diving too deep.

The four people not "on duty" will be free to work as they like. However, a normal and regular schedule will be continuously kept. Sleeping time, breakfast, lunch, briefing time in the evening and dinner have to be regular for psychologic reasons.

Beside this, it has been established that a soft, but strong authority has to be kept on board. The chief of the expedition will be the only responsable in every case. The best discipline on board, however, is obtained by the work and a regular schedule. Nobody will be allowed to smoke, and if a smoker is selected for the trip, he will have to stop smoking several weeks prior to the departure. Some alcohol may be served on board if required but only under the skipper control, for instance once a day during the briefing time. Everybody will have a berth where he can stay "far" from the other one. No doctor will be on board as the mesoscaph is always able to surface just in a few minutes.

o o

o

A mother ship will continuously keep in touch with the mesoscaph. This ship could be any surface boat able to keep a very slow speed for days and weeks. It is a matter of fact that while the mesoscaph will drift north-

ward at an average speed of for instance 3,5 knots along the Florida coast, the surface ship will have to propulse itself southward with a speed of about 1 knot in order to move northward (and backwards) and to stay over the mesoscaph.

The mother ship will use conventional navigation system to know its position in relation with the shore and will keep continuous contact by sonar with the mesoscaph. It has not yet been established whether the mesoscaph will have to use continuously a kind of pinger to be received by the surface boat or if the pinger of the mother ship will be sufficient. In any case, the mesoscaph will have a pinger to be used for reestablishing contact in case of temporary lost. An underwater telephone will be used for phonic communications between the mesoscaph and the mother ship.

Incidently, the mesoscaph will also be equipped with normal radio communication device to be used while on the surface.

The mother ship could for instance be a 81 feet catamaran; this kind of boat has the advantage of presenting a good stability and a wide deck with a great working area. We already have a proposal for the renting of such a boat. Cost would be some 185,000 $ for purchase (fully equipped for the Gulf Stream project); renting price would be 460 $ per day, including the equip-

ment and the crew. A similar boat with a length of 100 feet or more if desired could also be obtained. By using the catamaran, a scientists team could also make the surface trip and coordinate its research work with the one of the mesoscaph.

o o

o

At 200 m deep, the average speed may be expected to be for the full trip some 1,5 to 2 knots, i.e. 36 to 48 nautical miles per day or about 1000 to 1500 nautical milesin one month. In other words, it looks reasonable to expect to join Florida to Nova Scotia in four to six weeks (Miami - Halifax by the Gulf Stream way being distant of about 1450 nautical miles).

o o

o

It is not probable that the mesoscaph will arrive after a one month drift at a place from where it will be able to propel itself alone to a harbor. More likely, once at the surface, it will need the aid of the mother ship to reach the coast; the mother ship aid could be either to tow the mesoscaph or to recharge once or more its battery, allowing it to navigate then like an ordinary submarine or surface boat.

## V. THE SCIENTIFIC PROGRAM

The scientific program will be established with oceanographic centers involved in the Gulf Stream project. However, it looks already probable that the following program will be seriously considered.

### a) Acoustic

The complete silence in which the craft will operate will make of it a remarkable acoustic platform :

- speed of sound can be measured
- natural sound level can be checked; according to the length of the mesoscaph, directional measurements can easily be made
- sound measurements in connection with visual observations may be attempted if conditions are favorable
- sound penetration into the deep scattering layers can be measured
- tape records of fish and other sea inhabitants voices could be used in order to try to attract similar animals close to the mesoscaph.

### b) Marine biology

Plankton, fish, sea mammals will probably surround

the mesoscaph for hours and days. We may be able to make excellent and rare direct observations. One of the observers should be a well trained marine biologist. It is to be expected that, from time to time, it will be necessary to escape the fish by propelling for a while in order to clear the portholes for other observations. Previous experiences with the mesoscaph showed that the view field can be nearly completely obstructed by fish if the water is not moving in relation with the craft.

We expect to have a 4" inside diameter tube joining two portholes and a small pump letting the water circulate through the tube. Part of this tube will be transparent in such a way that it will be possible to directly observe plankton and small fish living under their usual pressure and attracted "inside" the mesoscaph by the small artificial current produced by the pump. As the surrounding water will remain the same for hours or days, it will be possible to observe the daily evolution of the plankton.

We also could have a small TV camera mounted on a miniaturized submarine equipped with search light and attached to the mesoscaph by an electrical multiconductor cable. This small TV camera could still work even if temporarily "eaten" for instance by a shark or a squidd. Interesting pictures could then be made.

Let us mention here again the DSL in which we could spend hours and days making many observations that would be impossible without the mesoscaph.

c) Physics and physical oceanography

It will be easy to continuously record the temperature, the salinity, the PH and other characteristics of the water. During the Port St. Lucie Conference it appeared that these data are not the most important of the Gulf Stream project, but they are still interesting to be collected among others. They could be recorded automatically and continuously. Beside this, it will be possible and important to make gravity measurements (the mesoscaph should be stable enough to do it without difficulty), light intensity measurements, normal and macro photography and movy. We also plan to offer to several Companies the possibility of testing their equipments (like inertial guidance system and acoustic instruments) on board of the mesoscaph during the Drift.

## VI. POWER REQUEST WHILE UNDER WATER

| | total power | consumption per day | total consumption (42 days) |
|---|---|---|---|
| search light | 30 kw | 1 kwh | 42 kwh |
| inside lighting | 125 W | 1,5 kwh | 63 kwh |
| warm water | | 1 kwh | 42 kwh |
| kitchen | | 2 kwh | 84 kwh |
| freezer | 500 W | 1,2 kwh | 50,4 kwh |
| propulsion | 100 kw | 1 kwh | 42 kwh |
| underwater telephone : | | | |
| - listening | 3 W | 0,072kwh | 3 kwh |
| - sending | 25 W | 0,025kwh | 1 kwh |
| fathometer | 14 W | 0,084kwh | 3,5 kwh |
| | | | 330,9 kwh |
| various and reserve | | 10 kwh | 420 - kwh |
| | | | 750 - kwh |

## VII. COST ESTIMATE

a) Cost of the vehicle (construction)

| | |
|---|---|
| - Pressure hull, including ballast tanks, conning tower, keel 2 negative tanks | 100,000 $ |
| - heat treating hull | 12,000 $ |
| - machining door seals | 1,500 $ |
| - trim tanks | 5,000 $ |
| - piping | 5,000 $ |
| - valves | 2,000 $ |
| - sanitary fittings | 1,000 $ |
| - portholes | 1,500 $ |
| - pump | 1,000 $ |
| - air regeneration | 25,000 $ |
| - propulsion | 35,000 $ |
| - electrical fittings | 5,000 $ |
| - electrical cables | 20,000 $ |
| - solid-state converter | 35,000 $ |
| - fathometer | 3,000 $ |
| - underwater telephone | 4,000 $ |
| - television | 5,000 $ |
| - pressure gauge | 1,000 $ |
| - navigation instruments | 1,000 $ |
| - search lights | 1,500 $ |
| - magnetic valves | 5,000 $ |
| - various marine equipments | 1,000 $ |
| | 270,500 $ |

(continued)

| | |
|---|---|
| Report . | 270,500 $ |
| - inside fittings | 15,000 $ |
| - assembly hardware | 25,000 $ |
| - painting | 1,500 $ |
| - connectors | 1,500 $ |
| - battery | 40,000 $ |
| - salaries and laboratory expenses (10 months) | 50,000 $ |
| | 403,500 $ |

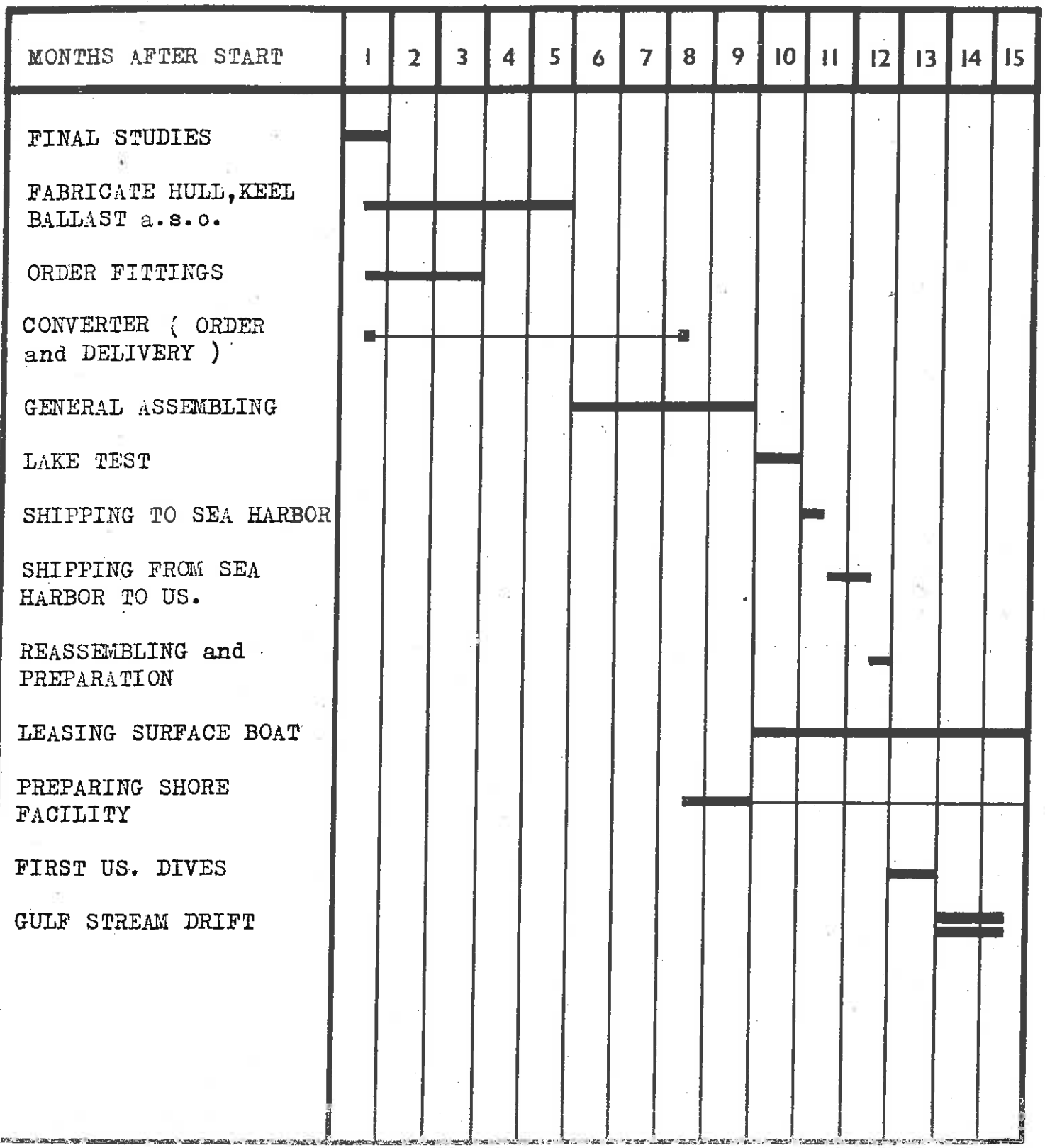
b) Total cost of the project

| | |
|---|---|
| - vehicle itself | 403,500 $ |
| - preliminary tests in the Lake of Geneva | 10,000 $ |
| - transportation from Switzerland to the United States | 26,500 $ |
| - dockage and shore facilities in Florida | 30,000 $ |
| - laboratory, travels and subsistance from the end of the construction to the end of the Gulf Stream Drift (5 months) | 80,000 $ |
| - insurances for the vehicle and liability (6 months) | 30,000 $ |
| - renting of the support vessel, including the crew (4 months) | 55,680 $ |
| | 635,680 $ |

(continued)

| | |
|---|---|
| Report | 635,680 $ |
| - various and reserve (10 %) | 63,560 $ |
| | 699,240 $ |
| - if desired : one pair of manipulators | 110,000 $ |
| | 809,240 $ |

# TIME - SCHEDULE



AND AFTER THE GULF STREAM DRIFT ...

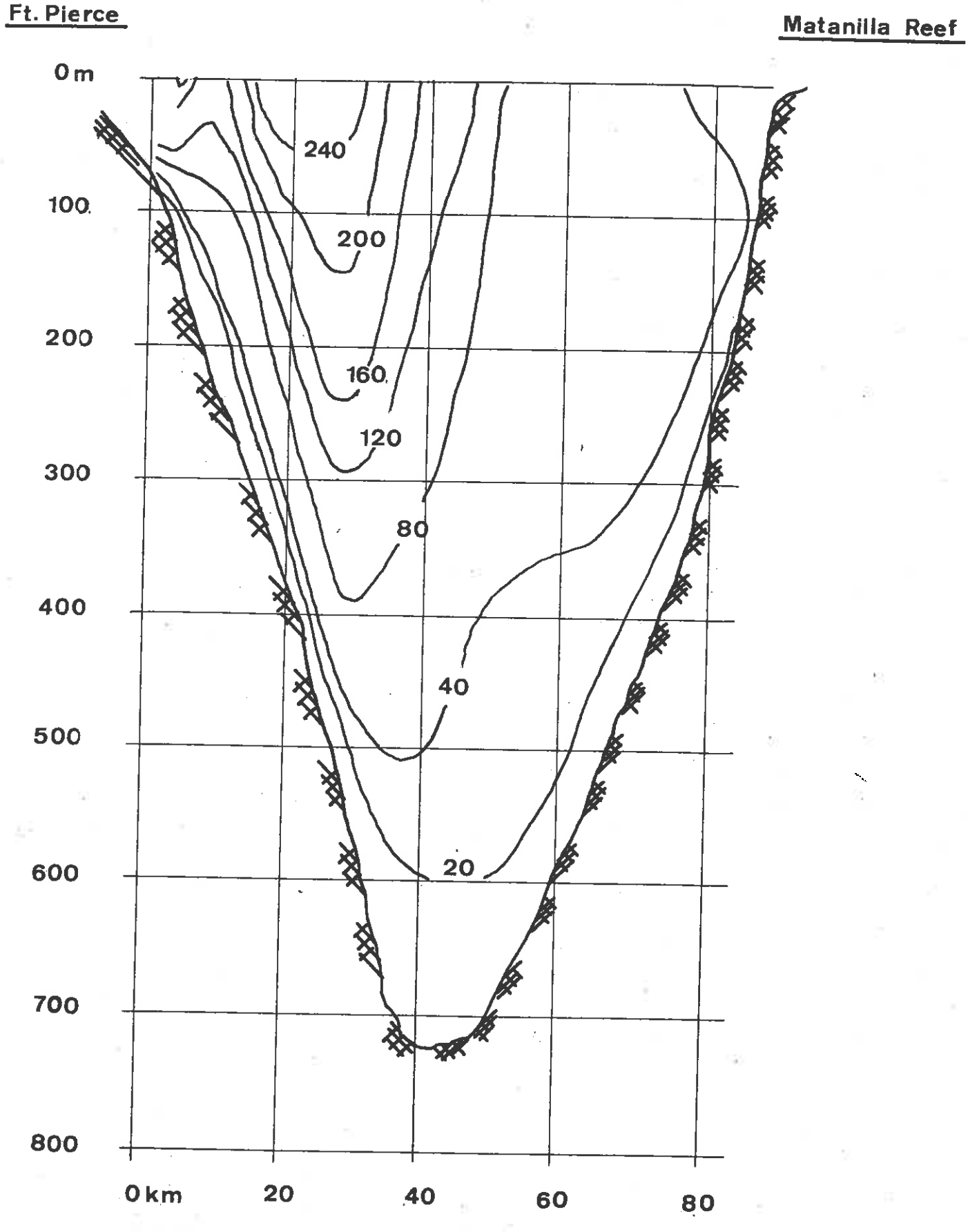
the PX - 15 will still be available. Many other similar drifts can be made into the Gulf Stream and/or into other underwater currents. Needless to say that oceanographers will have plenty of use for such a vehicle able to stay several weeks under water, able to carry for one day dives up to ten or more scientists, able to serve as an observation platform at any depth down to 2000 feet with several tons of scientific and technical equipment. At least 10 to 15 big oceanographic Centers in the United States could have a direct use of the PX - 15.

Beside this, at least 20 big American Companies in the Oil field could use the mesoscaph for research and underwater work.

Underwater mining, fishing and salvage are also more and more important, and it can be recalled here that the total investment in the sea between 1963 and 1972 has been established in the United States at 30 billion dollars for military, scientific and commercial application.

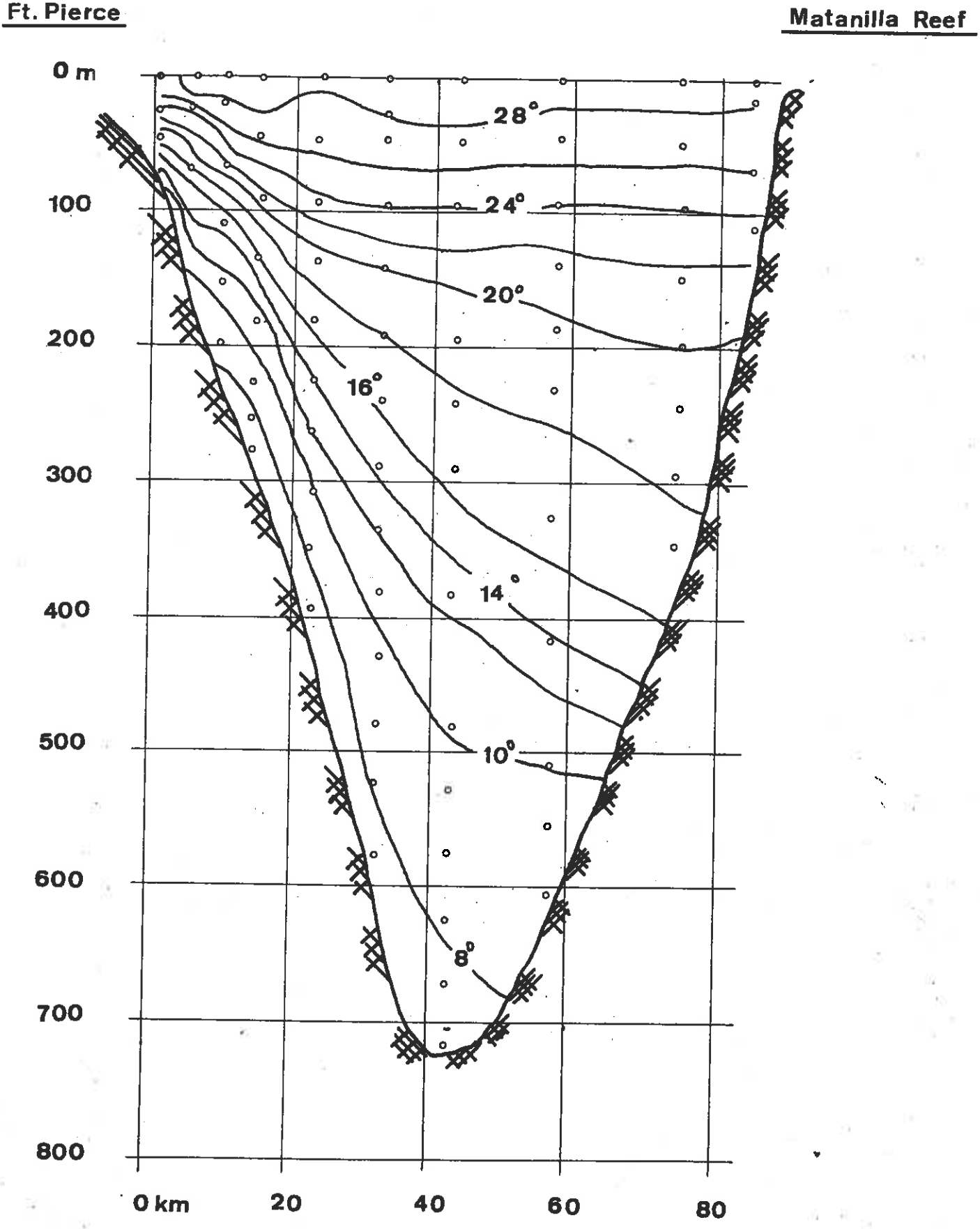
# S C H E D U L E S

# VELOCITY - CM/SEC



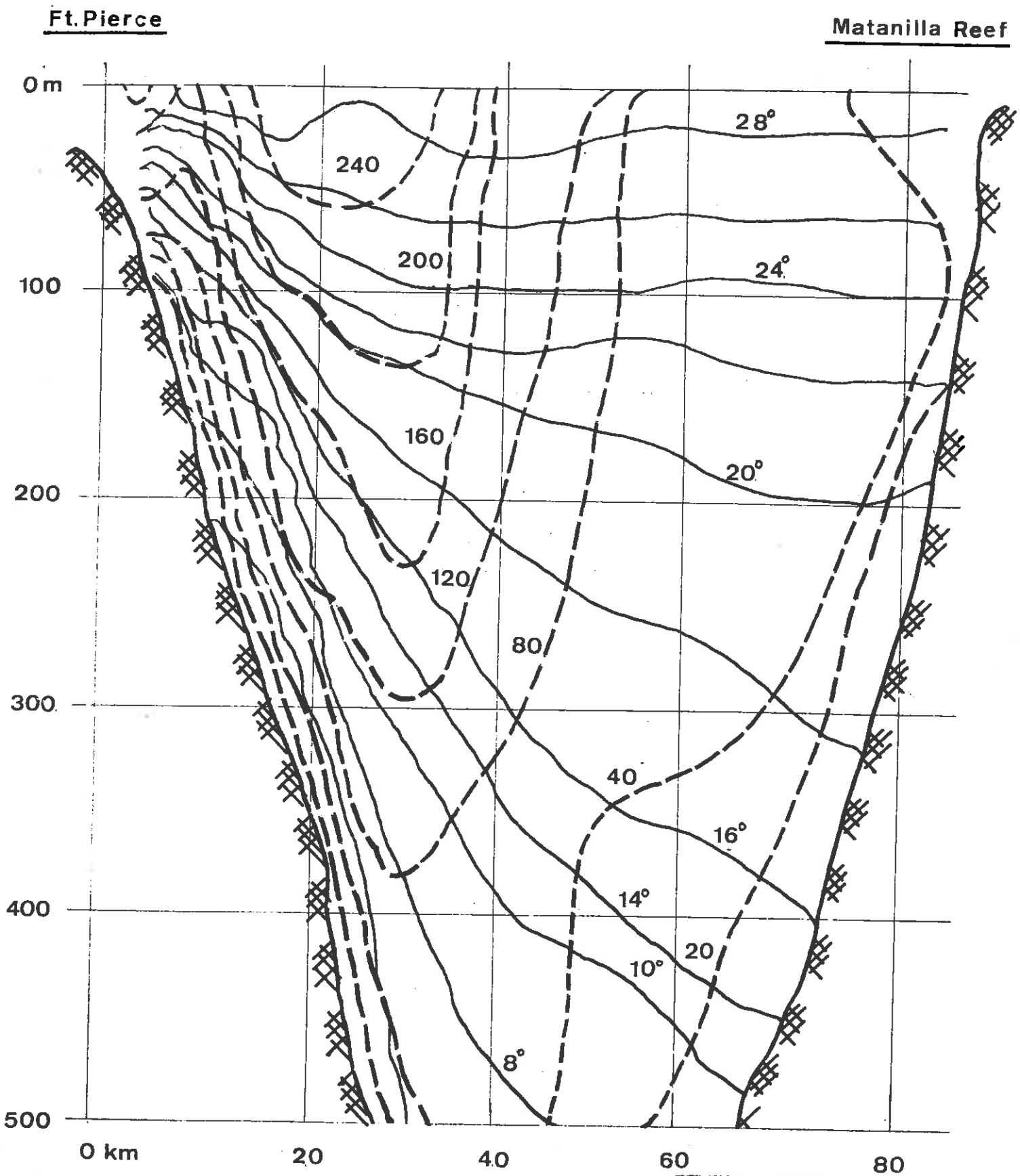

From MARINE LABORATORY - MIAMI

# TEMPERATURE PROFILE




From MARINE LABORATORY - MIAMI

# TEMPERATURE AND VELOCITY PROFILES.

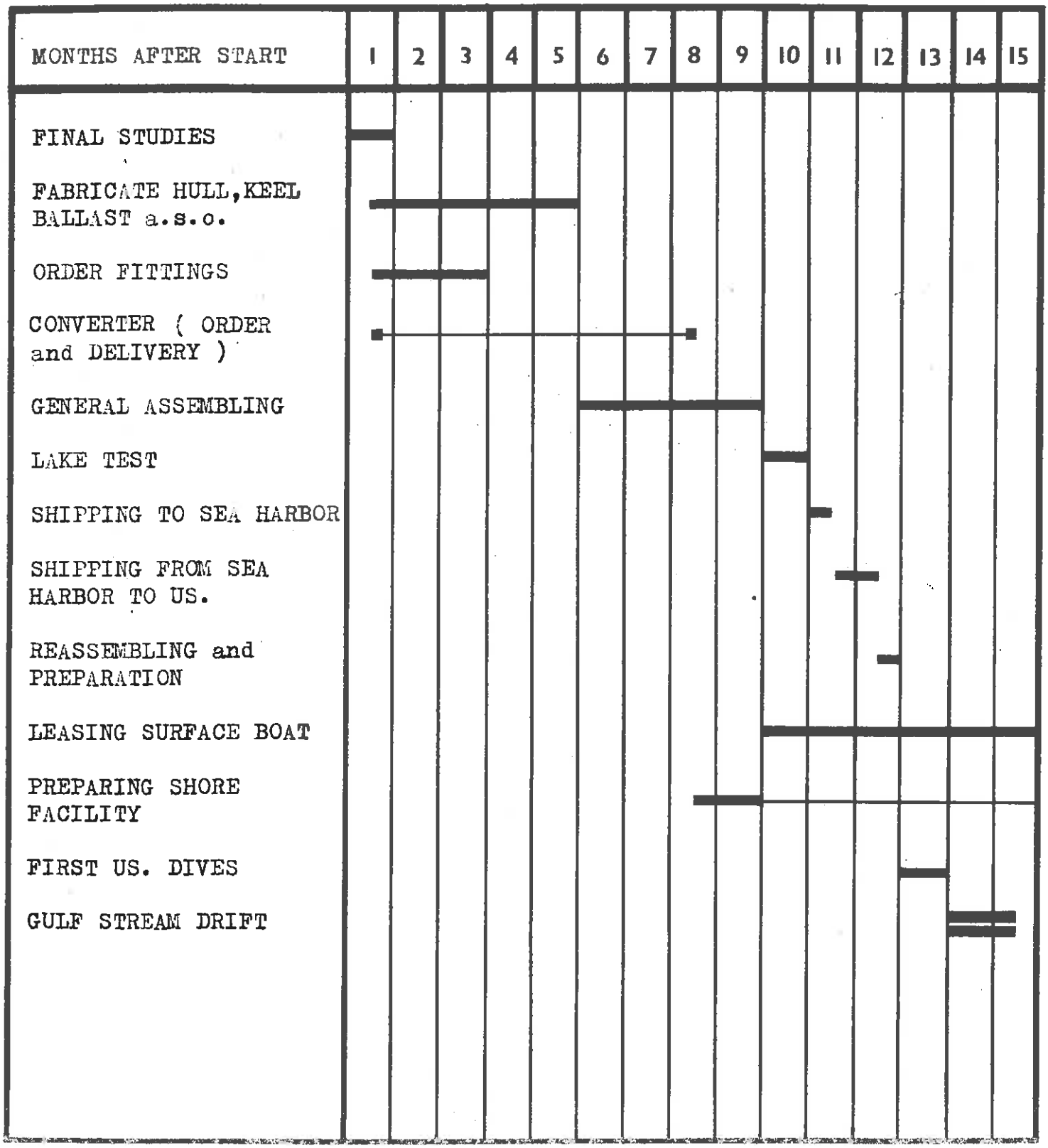


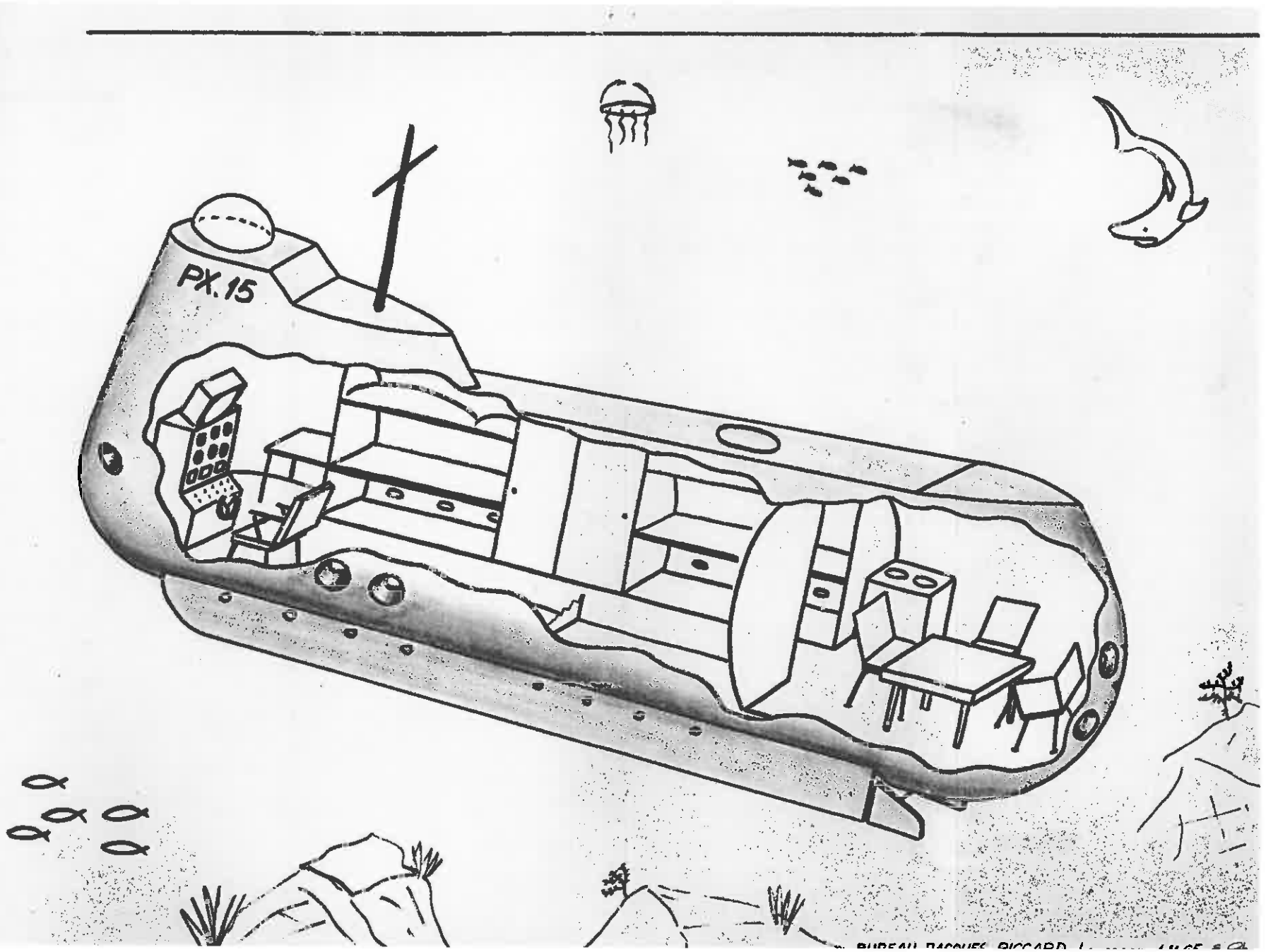

From MARINE LABORATORY - MIAMI

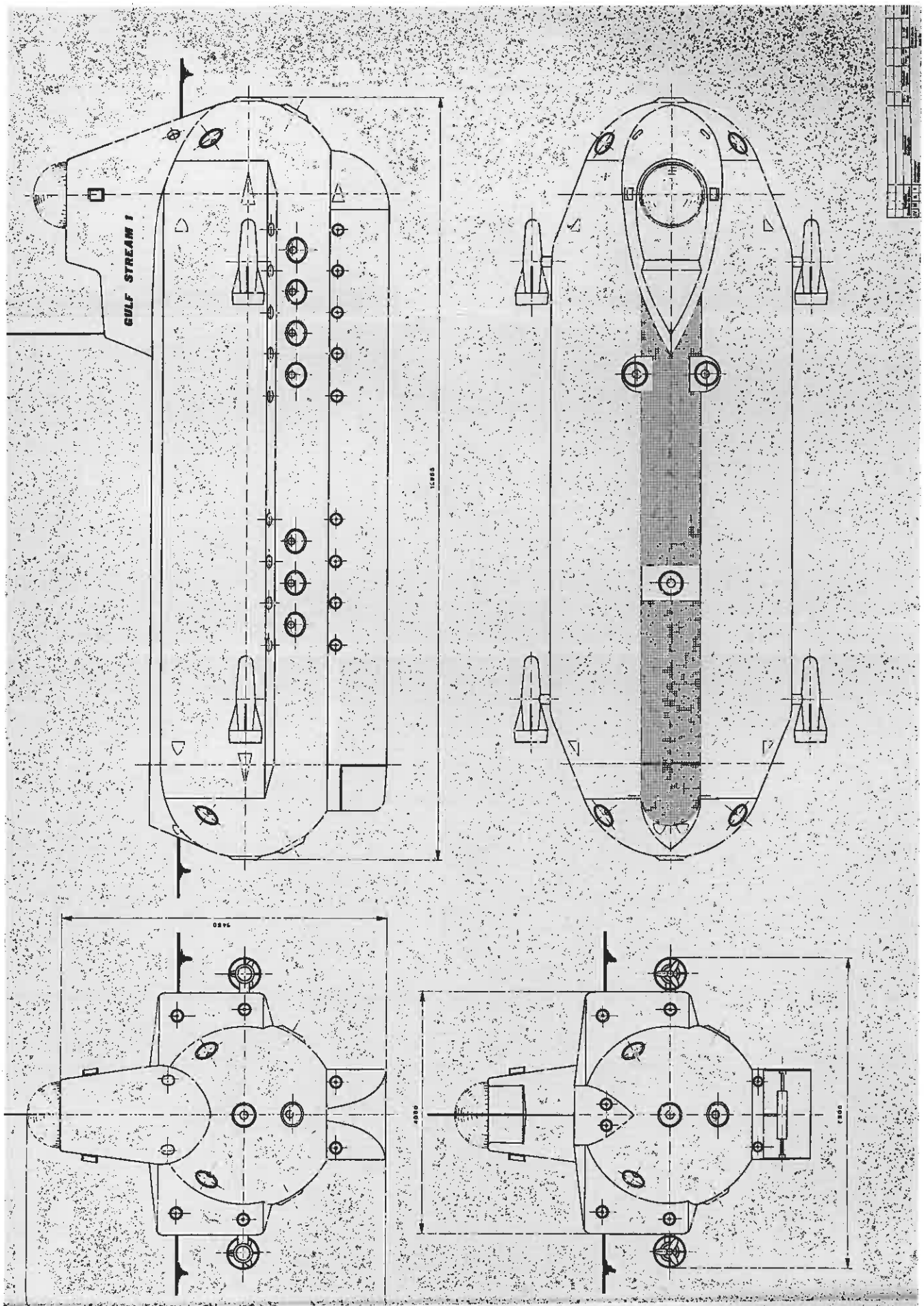
TEMPERATURE

VELOCITY ( cm/sec )

# TIME - SCHEDULE




PX.15


GULF STREAM I